

Factorial Design and Model for the Effect of Anti-Poaching Rules and Laws: A Case in South Africa, India and Kenya.

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Abstract

The purpose of this study is to use factorial design to investigate the effect of anti-poaching rules and laws in the reduction of illegal poaching of wildlife, and find a model for adequate description of the various observations in the data for the number of poached wildlife. Two-factor factorial design with mixed factors (country as the random factor and wildlife) as the mixed factor was used for the presentation and analysis of the data of the yearly number of poached wildlife for the period 2014 – 2017 recorded by KWS statistics in Kenya, South Africa and India. It resulted that the campaign on the anti-poaching rules and laws helped in the reduction of killed wildlife. There was also an indication that the effect of anti-poaching rules and laws in the reduction of poached wildlife in Kenya is different from that in South Africa and India. Also a mixed effect model was found to be adequate in the description of the various observations in the data for the number of poached wildlife as about 99% of variability in the mixed effect model on the number of poached wildlife is explained by the country (factor A), type of wildlife (factor B) and country-type of wildlife interaction.

Key Terms: factorial design, anti-poaching, illegal poaching, wildlife, random factor.

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1.0 INTRODUCTION

Poaching is referred to as the illegal hunting of wild animals. Poaching is not a sport but a crime since it poses a major threat to the animal population in the world. With adequate anti-poaching measures in the world, it has become a very lucrative organized crime globally and its value is estimated at 19 billion dollars per year. Elephants and rhinos are targeted by poachers for their tusks and horns where ivory is used in mass production for jewelry. The tusks of one elephant are worth tens of thousands of Euros. In June 2013 report by the IFAW estimates that the illicit wildlife trade is worth at least 14 billion Euros per year, ranking it the fourth largest global illegal activity after narcotics, counterfeiting and human trafficking. In late 2013, Kenya introduced new

tougher laws to combat poaching and illicit trade. A spokesman of the KWS said the new laws will give more incentives to the rangers who everyday risk their lives while doing their job.

In Kenya about 280 elephants and almost 60 rhinos have been killed by poachers in 2013, according to the Kenya wildlife service. A self-confessed poacher said he won't stop killing elephants because he needs money to support his family and he feels betrayed by the government. The hunters mostly belong to international organized poaching syndicates, highly profitable due to increasing demand. With this, the researcher is directed towards answering the question; to what extent are the introduced new and tougher laws been used to combat poaching and illicit trade as well as safeguard the lives of rangers? It is the expectation of all countries that illegal poaching of wildlife is stopped. It is in the direction of these expectation that this research is being conducted 1) to use factorial design to check the effectiveness of anti-poaching rules and laws and 2) to model the number of poached wildlife for adequate description of various observation in a data of the number of poached wildlife.

2.0 LITERATURE REVIEW

Country authorities have taken a number of critical steps towards implementing better anti-poaching policies in recent years and deployed a number of innovative tools to stamp out the abhorrent practice from high technology secure radios from French company Ellipse Projects, to mobile cyber tracker which has simplified patrols, to community engagement and ensuring that poachers face serious consequences. One major step forward came in 2013 when the KWS carried out an international tender, won by French engineering company Ellipse projects to upgrade the KWS's aging radio system. The environmentally friendly system is implemented by Ellipse projects works by way of solar powered radio infrastructure. The new radio system would help not only to protect biodiversity but also improve security of wardens and tourists.

Cyber Tracker app a boon to patrolling conservationists: Another technological tool that has also aided the surveillance work of Kenya anti-poaching forces, a mobile app and free GPS field data collecting system called Cyber Tracker. The spatial monitoring and reporting tool has greatly facilitated patrols particularly given that the Kenyan rangers tasked with monitoring and safeguarding protected land often have to cover vast swathes of land, sometimes on foot and often at night time.

Community understanding and real consequence for poachers: Community engagement has proven key in helping people understand the incredible value of Kenyan wildlife. By working with communities in close contact with wildlife, rangers are able to stem potential poachers in the bud and incite people to report instances of poaching.

Poaching in India: In India poaching is bolstered by high international demand for exotic animal and poverty-stricken forest communities who in some cases rapidly help the poachers make quick money. Even though India has strong laws to combat poaching due to weak enforcement it has not been entirely successful in curbing illegal hunting (poaching).

Indian Rhino: The Kaziranga National Park in India is home to world's only one-horned species of rhinoceroses. Poached and killed due to lucrative business opportunities and medicinal qualities of their horns, rhino horns fetch very high prices in the markets of Vietnam and China. Kaziranga National Park in Assam is the rhino capital of the world with 2401 rhinos in the 429 square kilometer park, according to 2015 census.

The government of India has intensified anti-poaching measures with 1247 forest personnel guarding the national park. The forest rangers deployed throughout the national park have been given the authority to shoot suspected poachers on the spot to save rhinos (Vira, 2017). However the forest guards on multiple occasions have been accused of extrajudicial killing and the garb of rhino protection. Recent evidence has come to light that rhinos along with ivory tusks (from elephants) might be responsible for funding terrorist organizations and international crime syndicates. Protection of rhinos is no longer a wildlife concern but an issue of national security (Poe. 2014).

Indian Elephant: The majestic Indian elephants are dwindling in numbers not only due to loss of habitat but also due to illegal poaching and organized wildlife crime syndicates involved in the process. Elephant ivory tusks have been used in human civilization since time immemorial and there exists a blooming ivory trade market even today. Since only male Asian elephants have tusks, they are being hunted ruthlessly, thereby skewing the sex ratio of the Indian elephants. This is not only affecting the rate of reproduction but is leading to a decline in genetic diversity required to ensure a healthy gene pool.

Elephants are also being hunted for medicinal use in Asian tradition, for meat and for international purposes. Elephant's tusks and other body parts are exported to China, Thailand and Japan where there is a huge demand for ivory carved Buddha sculptures. Most of the poaching cases in India are reported from the states of Kerala, Karnataka, Tarmil Nadu, Odisha, Uttarakhand and West Bengal. Even though the killing of elephants and ivory trading are punishable offences, more stringent measures should be put in place, lest elephants in India become a thing of the past.

Poaching in Kenya: Kenya, one of the many African countries affected by the poaching crisis saw a reduction in the number of rhino and elephant poached in 2017. 'Kenya lost nine rhinos and 60 elephants to poachers in 2017, compared to 14 rhinos and 96 elephants lost in the previous year' said Najib Balala Cabinet Secretary in the ministry of Tourism and Wildlife for Kenya. Before the establishment of KWS in 1989, inadequate support to conserve and manage Kenya's wildlife contributed to massive poaching, parks insecurity, low morale and inefficient within wildlife conservation department. This threatened the survival of both elephant and rhino species. This led to an establishment of a uniformed and disciplined KWS which consequently improved wildlife protection resulting in wildlife and tourism sectors stabilization. The role played by conservation bodies like the AWF among others to facilitate community and trans-border areas wildlife protection and coordination with KWS to achieve wildlife conservation and security related goals cannot be underrated. The recent AWF's capacity enhancement of KWS's canine detection unit by providing additional dogs and training support is evident. The unit is charged with detecting wildlife products contraband mainly ivory and rhino horn at entry and exit points such as airports, border points and seaports, thereby intercepting and disrupting the illicit trade. At global level, measures and efforts to tackle the threat posed by poaching and wildlife trophy trade have advanced focusing to reduce both supply and demand aspects of illegal wildlife trade. It involves mainly enhancing wildlife protection on ground (reducing supply) with escalated civic education campaigns at consumer markets (reducing demand). Both governmental and non-governmental organizations have been coordinating at both local and international levels in the process of eradicating the threat posed by poaching and trafficking of wildlife and their products.

Poaching in South Africa: Two types of rhino exist in South Africa, these being the black and southern white rhino. The southern white rhino has also been regarded as wonderful on conservation effort with just 50 of

these creatures existing in 1900 in KwaZulu-Natal to over 20,000 in the world today. In fact, 25% of these are on private land in South Africa. On the other hand, there were only 2,300 black rhinos in 1993, but through conservation efforts, the population were able to increase to roughly 5,000. In South Africa, there are an estimated 2,000 black rhinos with 23% of these being on private land. Pseudo Hunts were one of the first ways in which rhinos were poached. In this instance, traders used the specific exemption of sport hunting to obtain rhino horn. Often professional hunters would kill the animal and then register the kill under the name of the pseudo-hunter. There are also robberies and thefts of stockpiles of rhino horn. In 2014, 40 rhino horn were stolen from the safety of a governmental national parks department.

Finally there are traditional poaching methods where poachers enter into a game farm of the park, shoot and dehorn the rhino. These poaching methods have become more sophisticated and have led to increased bloodshed between poachers and law enforcement. It is also important to note that much of the rhino poaching takes place in the Kruger National Park and there is extensive involvement from the Mozambique side. Poachers and traffickers often use this porous border to engage in their criminal acts and are able to swiftly get back into Mozambique.

3.0 METHODOLOGY

Many experiments involve the study of the effect of two or more factors. In general, factorial designs are most efficient for this type of experiment. By factorial design we mean that in each complete trial or replication of the experiment all possible combinations of the levels of the factors are investigated. This chapter is therefore focused on the theoretical and conceptual frameworks for factorial design and models involved. The method of data collection used in the experiment is factorial design with both fixed factors and random factors combined to form factorial design with mixed factors.

Factorial designs: Factorial experiments are centered on the effect of two or more factors on a measured response (Milton & Arnold, 1995). For example in two-factor factorial design, if there are **a** levels of factor A and **b** levels of factor B, each replicate contains all **ab** treatment combinations (cells). A treatment combination (cell) is a level of factor A applied in conjunction with a level of factor B (that is ab = number of cells). If there are **n** observations (replicates) in each cell, they may be classified by means of a rectangular array where the rows represent the levels of one of the factors, say factor A, and columns represent levels of the other factor B. The total number of observations (replications) in the experiment is given by abn .

Denoting the k^{th} observation taken at the i^{th} level of factor A and j^{th} level of factor B by y_{ijk} the observations in a factorial experiment can be described by a model. The effect model is,

$$y_{ijk} = \mu + \alpha_i + \beta_j + (\alpha\beta)_{ij}$$

$$i = 1, 2, \dots, a$$

$$j = 1, 2, \dots, b$$

$$k = 1, 2, \dots, n$$

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where μ is the overall mean effect, α_i is the effect of the i^{th} level of the row factor A, β_j is the effect of the j^{th} level column factor B, $(\alpha\beta)_{ij}$ is the effect of the interaction between α_i and β_j and E_{ijk} is a random error component.

Statistical Analysis of the Fixed Effects Model.

Let $y_{i..}$ denote the total of all observations under the i^{th} level of factor A, $y_{.j.}$ denote the total of all observations under the j^{th} level of factor B, $y_{ij.}$ Denote the total of all observations in the ij^{th} cell, and $y_{...}$ denote the grand total of all the observations. Define $\bar{y}_{i..}$, $\bar{y}_{.j.}$, $\bar{y}_{ij.}$ and $\bar{y}_{...}$ as the corresponding row, column cells and grand averages.

Expressed mathematically as,

$$y_{i..} = \sum_{j=1}^b \sum_{k=1}^n y_{ijk} \quad , \quad y_{.j.} = \sum_{i=1}^a \sum_{k=1}^n y_{ijk} \quad , \quad y_{ij.} = \sum_{k=1}^n y_{ijk} \quad ,$$

$$y_{i..} = \sum_{i=1}^a \sum_{j=1}^b \sum_{k=1}^n y_{ijk}$$

$$\bar{y}_{i..} = \frac{y_{i..}}{bn} \quad i = 1, 2, \dots, a$$

$$\bar{y}_{.j.} = \frac{y_{.j.}}{an} \quad j = 1, 2, \dots, b$$

$$\bar{y}_{ij.} = \frac{y_{ij.}}{n} \quad i = 1, 2, \dots, a \quad , \quad j = 1, 2, \dots, b$$

$$\bar{y}_{...} = \frac{y_{...}}{abn}$$

The total corrected sum of squares may be written as

$$SS_T = SS_A + SS_B + SS_{AB} + SS_E$$

The number of degrees of freedom associated with each of squares is,

Effect	Degrees of freedom
A	$a - 1$
B	$b - 1$
AB	$(a - 1)(b - 1)$
Error	$ab(n - 1)$
Total	$abn - 1$

However, manual computing formulas for the sums of squares may be obtained easily. The total sum of squares is computed as usual as,

$$SS_T = \sum_{i=1}^a \sum_{j=1}^b \sum_{k=1}^n y_{ijk}^2 - \frac{y_{...}^2}{abn}$$

The sum of squares for the main effects is,

$$SS_A = \frac{1}{bn} \sum_{i=1}^a y_{i..}^2 - \frac{y_{...}^2}{abn} \quad \text{and}$$

$$SS_B = \frac{1}{an} \sum_{j=1}^b y_{.j.}^2 - \frac{y_{...}^2}{abn}$$

It is convenient to obtain the SS_{AB} in two stages. First we compute the sum of squares between the ab cell totals, which is called the sum of squares due to 'subtotals';

$$SS_{\text{subtotals}} = \frac{1}{n} \sum_{i=1}^a \sum_{j=1}^b y_{ij}^2 = \frac{y^2 \dots}{abn}$$

This sum of squares also contains SS_A and SS_B .

Therefore, $SS_{AB} = SS_{\text{subtotals}} - SS_A - SS_B$

We may compute SS_E by subtraction as,

$$SS_E = SS_T - SS_{AB} - SS_A - SS_B$$

$$\text{Or } SS_E = SS_T - SS_{\text{subtotals}}$$

Table 3: The Analysis of Variance Table for the Two-Factor Factorial, Fixed Effects Model.

Source of Variation	Sum of Squares	Degrees of Freedom	Mean Squares	Fo
A treatment	SS_A	$a - 1$	$MS_A = \frac{SS_A}{a-1}$	$F_o = \frac{MS_A}{MS_E}$
B treatments	SS_B	$b - 1$	$MS_B = \frac{SS_B}{b-1}$	$F_o = \frac{MS_B}{MS_E}$
Interaction	SS_{AB}	$(a-1)(b-1)$	$MS_{AB} = \frac{SS_{AB}}{(a-1)(b-1)}$	$F_o = \frac{MS_{AB}}{MS_E}$
Error	SS_E	$ab(n-1)$	$MS_E = \frac{SS_E}{ab(n-1)}$	
Total	SS_T	$abn - 1$		

Advantages of factorial designs: Factorial designs are more efficient than one-factor-at-a-time experiments. Furthermore a factorial design is necessary when interaction may be presented to avoid misleading conclusions. Secondly factorial designs allow the effects of a factor to be estimated at several levels of other factors, yielding conclusions which are valid over a range of experimental conditions (Montgomery, 2001).

4.0 RESULTS AND DISCUSSION

In an attempt to reduce illegal killing of wildlife especially elephants for their tusks and rhinos for their horns the key stakeholders have taken a number of steps towards implementing better anti-poaching policies in recent years and deployed a number of innovative tools to stamp out the abhorrent practice. Government authorities at times undertake research on several ways of wildlife poaching to generate data which is eventually analyzed to facilitate the guidance for selecting the best process and counter measures, leading to identification of the best policy for wildlife poaching reduction.

Data collection and presentation: With the aim of making inferences about the effect of anti-poaching rules and laws in an attempt to reduce illegal wildlife killings in many countries, at least one of the factors involved in the study should be random. Consequently by simple random sampling, three countries (Kenya, South Africa and India) were selected out of the many countries who have tried to safeguard elephants and

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rhinos from illegal killings. The data was collected from the respective country's authorities websites is based on the yearly number of poached wildlife for the period 2013 – 2017. The data is as shown in table 4.

TABLE 4: Raw data display of the number of poached wildlife for the period 2014 – 2017.

ROW	COUNTRY	TYPE OF WILDLIFE	NO. POACHED
1	KENYA	ELEPHANTS	164
2	KENYA	ELEPHANTS	96
3	KENYA	ELEPHANTS	86
4	KENYA	ELEPHANTS	80
5	SOUTH AFRICA	ELEPHANTS	2
6	SOUTH AFRICA	ELEPHANTS	22
7	SOUTH AFRICA	ELEPHANTS	46
8	SOUTH AFRICA	ELEPHANTS	68
9	INDIA	ELEPHANTS	22
10	INDIA	ELEPHANTS	41
11	INDIA	ELEPHANTS	21
12	INDIA	ELEPHANTS	18
13	KENYA	RHINOS	39
14	KENYA	RHINOS	11
15	KENYA	RHINOS	10
16	KENYA	RHINOS	9
17	SOUTH AFRICA SOUTH AFRICA	RHINOS	1215
18	SOUTH AFRICA	RHINOS	1175
19	SOUTH AFRICA	RHINOS	1054
20	INDIA	RHINOS	1028
21	INDIA	RHINOS	35
22	INDIA	RHINOS	24
23	INDIA	RHINOS	21
24		RHINOS	13

Table 5: Animal poaching data, in two-factor factorial design presentation for the effects of Anti-Poaching Rules and Laws.

	Type of Animal Factor B			
Country Factor A	No. of Elephants (j = 1)	No. of Rhinos (j = 2)	Total	Means
Kenya (i = 1)	164 96 86 80 y _{11.} = 426	39 11 10 9 y _{12.} = 69	495	61.875

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	$\bar{y}_{11.} = 106.5$	$\bar{y}_{12.} = 17.25$		
South Africa (i = 2)	2 22 46 68 $y_{21.} = 138$ $\bar{y}_{21.} = 34.5$	1215 1175 1054 1028 $y_{22.} = 4,472$ $\bar{y}_{22.} = 1,118$	4610	576.25
India (i = 3)	22 41 21 18 $y_{31.} = 102$ $\bar{y}_{31.} = 25.5$	35 24 21 13 $y_{32.} = 93$ $\bar{y}_{32.} = 23.25$	195	24.375
Total (.j.)	666	4634	5,300	
Means ($\bar{y}_{.j.}$)	55.5	386.17		220.83

Table 4.3: Poaching data showing the cell means, the row levels means and their corresponding percentage number of poached animals for the effect of anti-poaching rules and laws.

	Type of animal (Factor B)		Means	Percentage of the number of animals
Country (Factor A)	Number of Elephants	Number of Rhinos	$\bar{y}_{i..}$	%
Kenya (j = 1)	$\bar{y}_{11.} = 106.5$	$\bar{y}_{12.} = 17.25$	$\bar{y}_{1..} = 61.875$	9.3%
South Africa (j = 2)	$\bar{y}_{21.} = 34.5$	$\bar{y}_{22.} = 1,118$	$\bar{y}_{2..} = 576.25$	87%
India (j = 3)	$\bar{y}_{31.} = 25.5$	$\bar{y}_{32.} = 23.25$	$\bar{y}_{3..} = 24.375$	3.7%

A technique of statistical inference called significance testing, precisely analysis of variance is to be used to assist in comparing the effect of anti-poaching laws and rules in three countries, which could be extended to other countries.

Analysis Of Variance

Using significance level (α) of 0.05 throughout, and with two factor factorial design with mixed factors, the calculated data

$$\begin{aligned}
 SS_T &= \sum_{i=1}^3 \sum_{j=1}^2 \sum_{k=1}^4 y_{ijk}^2 - \frac{y_{...}^2}{abn} \\
 &= 164^2 + 96^2 + 56^2 + \dots + 13^2 - \frac{5300^2}{24} \\
 &= 5,088,850 - 1,170,416.67 = 3,918,433.33 \\
 SS_A &= \frac{1}{bn} \sum_{i=1}^3 y_{i..}^2 - \frac{y_{...}^2}{abn} \\
 &= \frac{1}{8} (495^2 + 4610^2 + 195^2) - \frac{5300^2}{24}
 \end{aligned}$$

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$$= 2,691,893.75 - 1,170,416.67$$

$$= 1,521,477.083$$

$$SS_B = \frac{1}{an} \sum_{i=1}^3 y_{j..}^2 - \frac{y_{...}^2}{abn}$$

$$= \frac{1}{12} (666^2 + 4634^2) - \frac{5300^2}{24}$$

$$= 1,826,459.333 - 1,170,416.67$$

$$= 656,042.66$$

$$SS_{\text{sub totals}} = \frac{1}{n} \sum_{i=1}^3 \sum_{j=1}^2 y_{ij.}^2 - \frac{y_{...}^2}{abn}$$

$$= \frac{1}{4} \{426^2 + 69^2 + 138^2 + 4,472^2 + 102^2 + 93^2\} - \frac{5300^2}{24}$$

$$= 5,055,779.5 - 1,170,416.67$$

$$= 3,885,362.83$$

$$SS_{AB} = SS_{\text{Subtotals}} - SS_A - SS_B$$

$$= 3,885,362.83 - 1,521,477.083 - 656,042.66$$

$$= 1,707,843.087$$

Table 6: ANOVA.

	SOURCE	D.F	SS	MS	F
1	(Sub-totals) Treatment combinations	5	3,885,362.83	777,072.566	422.95
2	Country	2	1,521,477.083	760,738.5415	414.064
3	Wildlife type Of animal	1	656,942.66	656,042.66	354.08
4	Country/ Type of animal	2	1,707,843.087	853,921.5435	464.78
5	Error	18	33,070.5	1,837.25	
6	Total	23	3,918,433.33		

$$R^2 = \frac{SS_{\text{model}}}{SS_{\text{total}}} = 99.16\%$$

The statements of the null hypothesis (H_0) and the alternative hypothesis (H_1) are as follows.

(i) For the hypothesis of no interactions

$$H_0: \delta_{AB}^2 = 0$$

$$H_1: \delta_{AB}^2 \neq 0$$

From the table for F distribution

$$F_{\alpha(a-1)(b-1), ab(n-1)} = F_{0.05(2,18)} = 3.55$$

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Since calculated F for wildlife type – country interaction (F_{AB}) is equal to $464.78 > F_{0.05(2,18)} = 3.55$, $F_{AB} = 464.78$ is significant.

Therefore $H_0: \delta^2_{AB} = 0$ is rejected with the conclusion that there is statistical evidence that there is interaction between country (factor A) and type of animal (factor B). This also gives the general indication that the type of animal poached is dependent of the country (factor B).

(ii) The analysis is continued by the hypothesis of no difference among the treatment means as

$$H_0: \delta^2_{Tr} = 0$$

$$H_1: \delta^2_{Tr} \neq 0$$

From the table for F distribution

$$F_{\alpha(ab-1), ab(n-1)} = F_{0.05(5,18)} = 2.77$$

Since calculated F for treatment combinations means differences (F_{Tr}) above is equal to $422.95 > F_{0.05(5,18)} = 2.77$, the treatment combination variance is significant. Hence:

$H_0: \delta^2_{Tr} = 0$ is rejected with the conclusion that there is statistical evidence that there is difference in variability among the cell (treatment combination) means.

Multiple comparison test.

Using multiple comparisons test, precisely Turkey's test, to discover the specific difference between the cell means, that is finding out whether the number of animals poached in Kenya on elephants and rhinos differ from those recorded in South Africa and India, the type of animal factor B is fixed at its levels of the number of elephants and rhinos. The Turkey's test is then applied to the means of country (factor A) at the respective levels of type of animal. The test statistic for Turkey's test is given by:

$$T_{\alpha} = q_{\alpha[ab(n-1)]} \sqrt{\frac{MES}{n}}$$

$$T_{0.05} = q_{0.05[3,18]} \sqrt{\frac{1.837.25}{4}}$$

$$= 3.609 \sqrt{\frac{1.837.25}{4}}$$

$$= 77.347$$

(i) The means of the number of elephants poached in Kenya, South Africa and India are 106.5, 34.5 and 25.5 respectively.

(ii) The means of the number of poached rhinos recorded in Kenya, South Africa and India are 17.25, 1,118 and 23.25 respectively.

The pair wise comparisons for (i) and (ii) respectively yield

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$$|\bar{y}_{21} - \bar{y}_{11}| = |34.5 - 106.5| = 72$$

$$|\bar{y}_{31} - \bar{y}_{11}| = |25.5 - 106.5| = 81$$

$$|\bar{y}_{31} - \bar{y}_{21}| = |25.5 - 34.5| = 9$$

$$|\bar{y}_{22} - \bar{y}_{12}| = |1,118 - 17.25| = 1,100.75$$

$$|\bar{y}_{32} - \bar{y}_{12}| = |23.25 - 17.25| = 6$$

$$|\bar{y}_{32} - \bar{y}_{22}| = |23.25 - 1,118| = 1,094.75$$

Since

$$|\bar{y}_{21} - \bar{y}_{11}| = 72, \quad |\bar{y}_{32} - \bar{y}_{12}| = 6 \quad \text{and} \quad |\bar{y}_{31} - \bar{y}_{21}| = 9$$

Are all less than $T_{0.05} = 77.347$, the number of poached elephants are not significantly different in Kenya and South Africa also in India and South Africa. Again there is no different in the number of poached rhinos in India and Kenya. Here the effect of anti-poaching rules and laws is the same.

Since $|\bar{y}_{21} - \bar{y}_{11}| = 81$

$$|\bar{y}_{22} - \bar{y}_{12}| = 1,100.75$$

$$|\bar{y}_{32} - \bar{y}_{22}| = 1,094.75$$

Are all greater than $T_{0.05} = 77.347$, the number of poached rhinos are significantly different in South Africa and Kenya, also in India and South Africa.

Again there is a significant difference in the number of poached elephants in India and Kenya.

Hence the effect of the anti-poaching rules and laws are not the same.

Model for the number of wildlife poached.

The effect model

$$y_{ijk} = \mu + \alpha_i + \beta_j + (\alpha\beta)_{ij} + E_{ijk}$$

where $i = 1, 2, \dots, a$, $j = 1, 2, \dots, b$ and $k = 1, 2, \dots, n$

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is considered instead of the regression model. Since the design is two-factor factorial design with mixed effects, the terms are defined as

μ = the overall mean number of poached wild animals

α_i = the dependent random treatment (level) effect of country factor (A) independent of E_{ijk} and normally distributed with mean zero and variance δ_A^2

β_j = the fixed treatment (level) effect of wild life type (factor B) such that

$$\sum_{j=1}^b \beta_j = 0$$

$(\alpha\beta)_{ij}$ = the country wildlife interaction effect which is assumed a random status independent and normally distributed with mean zero and variance δ_{AB}^2

E_{ijk} = the measure of deviations of y_{ijk} from the $(ij)^{th}$ cell mean of the number of poached wildlife μ_{ij} .

Estimating the parameters of the model, the fixed factor effects (μ and β_j) are respectively estimated as,

$$\hat{\mu} = \bar{y} \dots = 220.83$$

$$\text{And } \hat{\beta}_j = \bar{y}_{.j} - \bar{y} \dots$$

The variance component δ_A^2 , δ_{AB}^2 and δ^2 (for the random effects) are also respectively estimated as,

$$\delta_A^2 = \frac{MS_A - MS_E}{bn} = \frac{760738.5435 - 1837.25}{2 \times 4} = 94,862.66$$

$$\delta_{AB}^2 = \frac{MS_{AB} - MS_E}{n} = \frac{853,921.5435 - 1837.25}{4} = 213021.0734$$

$$\hat{\delta}^2 = MSE = 1835.25$$

Since none of the estimated variance components values is zero, as confirmed by the corresponding significant p-values, the terms in the effect model are effective. Hence the mixed effect model,

$$y_{ijk} = \mu + \alpha_i + \beta_j + (\alpha\beta)_{ij} + E_{ijk}$$

adequately describes the observations above, the sum of squares model given by,

$$\begin{aligned} SS_{\text{model}} (SS_{\text{Tr}}) &= SS_A + SS_B + SS_{AB} \\ &= 1,521,477.083 + 656,042.66 + 1,707,843 = 3,885,362.83 \end{aligned}$$

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$$\text{Hence } R^2 = \frac{SS_{\text{model}}}{SS_T} = \frac{3,885,362.83}{3,918,433.33} = 0.99$$

This means that about 99% of the variability in the number of wildlife poached is explained by the country (factor A), type of wildlife (factor B) and the interaction between country and type of wildlife.

Model adequacy checking.

Using equation $E_{ijk} = y_{ijk} - \bar{y}_{ij.}$ to find the residuals of the number of poached wildlife and represented in the following table.

Table 6: Residual table

COUNTRY	WILDLIFE TYPE	NO. OF POACHEDANIMALS	WILDLIFE TYPE	RESIDUALS	FITS
Kenya	Elephants	164	1	57.5	106.5
Kenya	Elephants	96	1	-10.5	106.5
Kenya	Elephants	86	1	-20.5	106.5
Kenya	Elephants	80	1	-26.5	106.5
s. Africa	Elephants	2	1	-32.5	34.5
S. Africa	Elephants	22	1	-12.5	34.5
S. Africa	Elephants	46	1	11.5	34.5
S. Africa	Elephants	68	1	33.5	34.5
India	Elephants	22	1	-3.5	25.5
India	Elephants	41	1	15.5	25.5
India	Elephants	21	1	-4.5	25.5
India	Elephants	18	1	-7.5	25.5
Kenya	Rhinos	39	2	21.75	17.25
Kenya	Rhinos	11	2	-6.25	17.25
Kenya	Rhinos	10	2	-7.25	17.25
Kenya	Rhinos	9	2	-8.25	17.25
S. Africa	Rhinos	1215	2	97	1118
S. Africa	Rhinos	1175	2	57	1118
S. Africa	Rhinos	1054	2	-64	1118
S. Africa	Rhinos	1028	2	-90	1118
India	Rhinos	35	2	11.75	23.25
India	Rhinos	24	2	0.75	23.25
India	Rhinos	21	2	-2.25	23.25
India	Rhinos	13	2	-10.25	23.25

Parameter estimation.

Given the mixed-effect model for the number of poached wildlife as,

$$y_{ijk} = \mu + \alpha_i + \beta_j + (\alpha\beta)_{ij} + E_{ijk}$$

The parameters (μ , α_i , β_j and $(\alpha\beta)_{ij}$) are respectively estimated as,

$$\hat{\mu} = \bar{y}...$$

that is the overall population mean is estimated by the grand mean number of poached wildlife both elephants and rhinos in all the three countries for the period 2014 – 2017.

$$\hat{\alpha}_i = \bar{y}_{i..} - \bar{y}_{...}$$

That is the row level effects are estimated by the corresponding row level mean minus the grand mean number of poached wildlife.

$$\hat{\beta}_j = \bar{y}_{.j.} - \bar{y}_{...}$$

That is, the row level effects are estimated by the corresponding column level mean minus the grand mean number of poached wildlife.

$$(\hat{\alpha\beta})_{ij} = \bar{y}_{ij.} - \bar{y}_{...} - (\bar{y}_{i..} - \bar{y}_{...}) - (\bar{y}_{.j.} - \bar{y}_{...})$$

That is the ij^{th} interaction effect is estimated by the corresponding ij^{th} cell mean minus the grand mean number of poached wildlife, the corresponding row level effect and the corresponding column level effect are simplified as,

26.

$$(\hat{\alpha\beta})_{ij} = \bar{y}_{ij.} - \bar{y}_{i..} - \bar{y}_{.j.} + \bar{y}_{...}$$

Also

$$E_{ijk} = y_{ijk} - \bar{y}_{ij.}$$

That is the, the error due to unexplained sources in the recording of an observation in the data for the number of poached wildlife is the observation minus the corresponding cell mean of the number of poached wildlife.

Neglecting the last term (E_{ijk}) of the mixed-effect model leads to the estimation of the fitted value as,

$$\hat{y}_{ijk} = \bar{y}_{ij.}$$

That is, each observation in the data for the number of poached wildlife per cell is estimated by the corresponding mean of the number of poached wildlife.

Prediction.

Table 7: Number of poached wildlife data, showing cell means, row level means, column level means and grand mean poached wildlife for the prediction of the various observations.

	Type of wildlife Factor B		Means
Country (Factor A)	Elephants (Numbers)	Rhinos (Numbers)	$\bar{y}_{i..}$

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Kenya (i = 1)	$\bar{y}_{11.} = 106.5$	$\bar{y}_{12.} = 17.25$	$\bar{y}_{1..} = 61.875$
South Africa (j = 2)	$\bar{y}_{21.} = 34.5$	$\bar{y}_{22.} = 1,118$	$\bar{y}_{2..} = 576.25$
India (k = 3)	$\bar{y}_{31.} = 25.5$	$\bar{y}_{32.} = 2325$	$\bar{y}_{3..} = 24.375$
Mean ($\bar{y}_{.j.}$)	$\bar{y}_{.1.} = 55.5$	$\bar{y}_{.2.} = 386.17$	$\bar{y}_{...} = 220.83$

With references to the table above,

$$\hat{\mu} = \bar{y}_{...}$$

$$= 220.83$$

If $\bar{y}_{i..} = \bar{y}_{1..} = 61.875$ then,

$$\hat{\alpha}_1 = 61.875 - 220.83 = -158.955$$

That is, the effect of Kenya (level 1 of factor A) on the number of elephants and rhinos is -158.955.

Also $\bar{y}_{.j.} = \bar{y}_{.1.} = 55.5$ implies,

$$\hat{\beta}_1 = \bar{y}_{.1.} - \bar{y}_{...}$$

$$= 55.5 - 220.83 = -165.33$$

That is the effect of poached elephants (level 1 of factor B) on the number of poached wildlife recording all the countries of Kenya, South Africa and India is -165.33

This further implies that

$$(\hat{\alpha}\hat{\beta})_{ij} = (\hat{\alpha}\hat{\beta})_{11}$$

$$= \bar{y}_{11.} - \bar{y}_{1..} - \bar{y}_{.1.} + \bar{y}_{...}$$

$$= 106.5 - 61.875 - 55.5 + 220.83$$

$$= 209.955$$

That is, the effect of the interaction between country and animal type of the number of poached wildlife in the three countries in Kenya and elephants combination cell is 209.955

$$E_{111} = y_{111} - \bar{y}_{11.}$$

$$= 164 - 106.5 = 57.5$$

That is, the error due to an unexplained source in the recording of the number of poached elephants in Kenya is 57.5

29.

To adequately describe an observation like 164 (the first observation) in the data for the data of poached wildlife is

$$y_{ijk} = y_{111}$$

$$= \mu + \alpha_i + \beta_j + (\alpha\beta)_{11} + E_{111}$$

$$= 220.83 + -158.955 + -165.33 + 209.955 + 57.5 = 164$$

Since $y_{111} = 164$ tallies with the first observation in the data shown in the above table. It implies that the mixed effect model adequacy describes the first observation (164).

The table below gives the summary of the sum of parameters of the mixed effect model, leading to the adequate description of the various observations in the data for the yearly poached wildlife for the period 2014 – 2017.

Table 4.7: Summary of the sum of the parameters of the mixed-effect model.

$$y_{ijk} = \mu + \alpha_i + \beta_j + (\alpha\beta)_{ij} + E_{ijk}$$

y_{ijk}	μ	α_i	β_j	$(\alpha\beta)_{ij}$	E_{ijk}	Result
y_{111}	220.83	-158.955	-165.33	209.955	57.5	64
y_{112}	220.83	-158.955	-165.33	209.955	-10.5	96
y_{113}	220.83	-158.955	-165.33	209.955	-20.5	86
y_{114}	220.83	-158.955	-165.33	209.955	-26.5	80
y_{121}	220.83	-158.955	165.34	-209.965	21.75	39
y_{122}	220.83	-158.955	165.34	-209.965	-6.25	11
y_{123}	220.83	-158.955	165.34	-209.965	-7.25	10
y_{124}	220.83	-158.955	165.34	-209.965	-8.25	9
y_{211}	220.83	355.42	-165.33	-376.42	-32.5	2
y_{212}	220.83	355.42	-165.33	-376.42	-12.5	22
y_{213}	220.83	355.42	-165.33	-376.42	11.5	46
y_{214}	220.83	355.42	-165.33	-376.42	33.5	68
y_{221}	220.83	355.42	165.34	376.41	97	1,118
y_{222}	220.83	355.42	165.34	376.41	57	1,175
y_{223}	220.83	355.42	165.34	376.41	-64	1,054
y_{224}	220.83	355.42	165.34	376.41	-90	1,028
y_{311}	220.83	-196.455	-165.33	166.455	-3.5	22
y_{312}	220.83	-196.455	-165.33	166.455	15.5	41
y_{313}	220.83	-196.455	-165.33	166.455	-4.5	21
y_{314}	220.83	-196.455	-165.33	166.455	-7.5	18
y_{321}	220.83	-196.455	165.34	-166.465	11.75	35
y_{322}	220.83	-196.455	165.34	-166.465	0.75	24
y_{323}	220.83	-196.455	165.34	-166.465	-2.25	21
y_{324}	220.83	-196.455	165.34	-166.465	-10.25	13

Discussion

Even though there are vast difference between the number of poached elephants in Kenya than those recorded in India and South Africa as displayed in table 4.1 and 4.3, again more rhinos appear to be poached in South Africa than in Kenya and India. It does not obvious that these differences must imply that the effect of anti-poaching rules and laws in the three countries are really different. Perhaps these observed differences in the data are the result of the total number of the wildlife in the three countries. It is clear that South Africa have a huge number of rhinos than Kenya and India. Again Kenya has a bigger number of elephants than South Africa and India.

From the analysis of variance table the test for interaction between country and type of wildlife at significance level $\alpha = 0.05$ being significant gives the general indication that wildlife type is dependent of country. This could also mean that the effect of anti-poaching laws depends on a country. This further necessitated the test for the differences between treatment combination (cell) means, which was also significant at $\alpha = 0.05$. This means that there was enough statistical evidence that there is at least a difference between the number of poached elephants and rhinos in Kenya, South Africa and India respectively at $(\alpha) = 0.5$. This also gives a clear indication that the effect of anti-poaching rules and laws in the reduction of poached wildlife in Kenya is different from that in South Africa and India.

Since two factor factorial design with mixed factors was employed in this study, it is reasonable that the effect of anti-poaching laws was not the same across all the three countries.

The parameters of the mixed-effect model,

$$y_{ijk} = \mu + \alpha_i + \beta_j + (\alpha\beta)_{ij} + E_{ijk}$$

Were well estimated with the fixed factor effect terms (μ and β_j) and the random factor effect terms (α_i , $(\alpha\beta)_{ij}$ and E_{ijk}) all being fit in the model.

Also the coefficient of determination (R^2) = 0.99 proved that about 99% of variability in the mixed effect model of the number of poached wildlife is explained by country-type of wildlife type interaction. The residuals analysis for the model adequacy checking also proved that the mixed-effect model adequately describes the various observations in the data for wildlife, despite the inequalities in the variance which might have been caused by the ---- extreme residuals. How it is important to note that the mixed-effect model:

$y_{ijk} = \mu + \alpha_i + \beta_j + (\alpha\beta)_{ij} + E_{ijk}$ will basically be used for accurate and adequate description of the various observations in the data for the number of poached wildlife.

5.0 CONCLUSIONS AND RECOMMENDATIONS

The test of no interaction being significant at $\alpha = 0.05$ means that there is statistical evidence that wildlife type is not independent/is dependent of the country. Also the test of cell means difference was significant at $\alpha = 0.05$, giving the indication that the effect of anti-poaching is not the same across the three countries of Kenya, South Africa and India. This further gives indication that the campaign on anti-poaching has not gotten the same impact on number of poached wildlife across all the countries. Last but not least, the mixed-effect model:

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$y_{ijk} = \mu + \alpha_i + \beta_j + (\alpha\beta)_{ij} + E_{ijk}$ is appropriate and adequate in the description of the observation in the for the number of poached wildlife.

Following the successful use of the two-factor factorial design in this study, it is recommendation that 2^k , 3^k etc factorial design be used in analyzing the effect of anti-poaching rules studies based on the fact that the k factors involved are of equal levels. Also, it is recommended that improved ant-poaching rules should be introduced and uniformly adhered to in all the countries to stop the market of wildlife products. Anti-poaching education through media be carried out in all countries. Finally, it is recommended that further study or research on wildlife poaching and illegal hunting be discouraged taking into consideration other wildlife apart from rhinos and elephants that poachers sell their tasks. Other wildlife such as antelopes, gazelles, rabbits to prevent extension.

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